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Direct Bandgap group IV Materials

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Direct bandgap group IV materials have been long sought for in both academia and industry for the implementation of photonic devices. This proposal works on the fundamental issues and planar photonic devices that are suitable for the integration with the group IV based electronic devices. In this project, we have accomplished (a) direct bandgap group IV materials of GeSn, (b) GeSn-based planar light-emitting diode operated at near infrared with direct emission, and (c) the first planar photodetector (Appl. Phys. Lett. 105, 231109 (2014) and references within) This move a step forward toward the monolithic integration of optic and electronic devices in a single chip (all group IV materials). Still, there are two other components (waveguide channel and modulator) that is needed for the all group IV materials optoelectronic and this will be the main targets for next project.

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Abstract:

Direct bandgap group IV materials have been long sought for in both academia and industry for the implementation of photonic devices. This proposal works on the fundamental issues and planar photonic devices that are suitable for the integration with the group IV based electronic devices. In this project, we have accomplished (a) direct bandgap group IV materials of GeSn, (b) GeSn-based planar light-emitting diode operated at near infrared with direct emission, and (c) the first planar photodetector (Appl. Phys. Lett. 105, 231109 (2014) and references within) This move a step forward toward the monolithic integration of optic and electronic devices in a single chip (all group IV materials). Still, there are two other components (waveguide channel and modulator) that is needed for the all group IV materials optoelectronic and this will be the main targets for next project.

Introduction:

The energy band of group IV element of Si and Ge are indirect. This means, in the optical process of emission, electrons at the conduction band minimum needs to

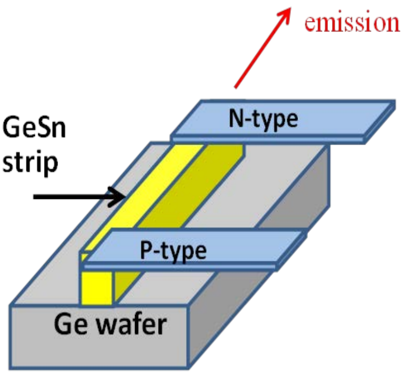
give up a finite momentum to recombine with holes at valence band minimum. As a consequence, only a fraction of electron can find the hole yielding a low emission efficiency. Similar observation also occurs in the absorption process. Therefore, these materials are not suitable for use as optical devices (optical emitter and photodetector). In the last couples of years, another group IV element-Sn is employed in the growth of group IV materials. The incorporation of Sn modulates the bandgap of the host IV-IV compounds, and, above a certain Sn composition, the energy band of the IV-IV compounds changes from an indirect to a direct bandgap as that of III-V compounds which are suitable for optical devices. This leads to the demonstration of GeSn-based light-emitting diodes (LEDs) and photodetectors (PDs). In these works, the LEDs (PDs) emit (collect) light from the surface of the sample (perpendicular to the wafer surface). However, for the integration with Si-based electronics, the devices need to emit (collect) light parallel to the wafer surface. In this project, we focus on planar GeSn-based photonic devices and the results on LEDs and PDs is demonstrated. Next stage, we propose to move to another horizon of the integration of optical emitter and detector which is the building block for optoelectronic.

This report is divided into the following three sections:

(a) Planar GeSn-based photonic devices－light-emitting diode and photodetector
(b) Related Publications

(a) Planar GeSn-based photonic devices－light emitting diode and photodetector

Sn-based direct bandgap group IV materials have been established in our laboratory and these results have been reported in several journals (see the report last year). In our previous work, the first GeSn-based planar LEDs is proposed and demonstrated. The LEDs is built upon a diode, which consists of an undoped layer. The sample is fabricated into a mesa strip, and electrical contacts are placed at two ends of the strip by ion implantation. The p-i-n structure lies in the plane of the Ge wafer. By applying external voltage across the electrical contact, the light emits from the side of the strip.



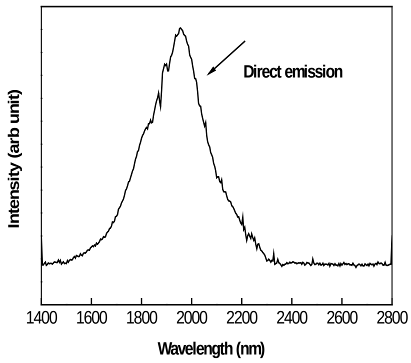


Fig. 3. (a) Left plot: Schematic plot of the proposed waveguided LED. (b) Right plot: EL spectrum

We like to point out that, the planar LED has the following advantages over the vertical LED: (a) As the length of the strip can be much greater than the thickness of the layer, the emission strength of the LED would be greater, resulting in a greater emission intensity as compared to the vertical LED. (b) The strip also functions as an optical cavity. (c) The structure can be integrated with most planar electronic devices, which is required for the integration of optoelectronic applications. With those advantages described above, in the next stage, we move to the laser structure which is desired in various applications.

Reference:

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(a) Related Publications (2014)

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(2) Structural and optical characteristics of Ge_{1-x}Snx/Ge superlattices grown on Ge-buffered Si(001) wafers, Jia-Zhi Chen,1 H. Li,1 H. H. Cheng, and Guo-En Chang, Optical Materials Express Vol. 4, Iss. 6, pp. 1178–1185 (2014).

(3) Electrical characteristics of Ni Ohmic contact on n-type GeSn, H. Li, H. H. Cheng, L. C. Lee, C. P. Lee, L. H. Su, and Y. W. Suen, Appl. Phys. Lett**.** **104**, 241904 (2014).

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